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**[TITLE]**

STORAGE PHOSPHOR PANEL, RADIATION IMAGE SENSOR AND METHODS OF MAKING  
5 THE SAME

**[RELATED APPLICATION]**

The application claims the benefit of US Provisional Application  
No. 60/455,240 filed March 17, 2003.

**[DESCRIPTION]****FIELD OF THE INVENTION**

15 The present invention relates to a storage (stimulable) phosphor  
panel suitable for use in medical X-ray radiography, and a method of  
making them.

**BACKGROUND OF THE INVENTION**

20 A well known use of storage phosphors is in the production of X-  
ray images. In US-A 3,859,527 a method for producing X-ray images with  
a photostimulable phosphor, which are incorporated in a panel, is  
disclosed. The panel is exposed to an incident pattern-wise modulated  
25 X-ray beam and as a result thereof the phosphor temporarily stores  
energy contained in the X-ray radiation pattern. At some interval  
after the exposure, a beam of visible or infra-red light scans the  
panel in order to stimulate the release of stored energy as light that  
is detected and converted to sequential electrical signals which become  
30 processed in order to produce a visible image. For this purpose the  
phosphor should store as much as possible of the incident X-ray energy  
and emit as little as possible of the stored energy before being  
stimulated by the scanning beam, thus showing prompt emission after X-

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ray exposure to an extent as low as possible. This is called "digital radiography" or "computed radiography".

Since in the above described X-ray recording systems the X-ray conversion screens are used repeatedly, it is important to provide them with an adequate topcoat for protecting the phosphor containing layer from mechanical and chemical damage. This is particularly important for photostimulable radiographic screens where screens are often transported in a scanning module - wherein the stimulation of the stored energy takes place - while not being encased in a cassette but is used and handled as such without protective encasing.

The image quality that is produced by any radiographic system using phosphor screen thus also in a digital radiographic system, depends largely on the construction of the phosphor screen. Generally, the thinner a phosphor screen at a given amount of absorption of X-rays, the better the image quality will be. This means that the lower the ratio of binder to phosphor of a phosphor screen, the better the image quality, attainable with that screen, will be. Optimum sharpness can thus be obtained when screens without any binder are used. Such screens can be produced, e.g., by physical vapor deposition, which may be thermal vapor deposition, sputtering, electron beam deposition or other of phosphor material on a substrate. However, this production method can not be used in order to produce high quality screens with every arbitrary phosphor available. The mentioned production method leads to the best results when phosphor crystals with high crystal symmetry and simple chemical composition are used.

The use of alkali metal halide phosphors in storage screens or panels is well known in the art of storage phosphor radiology and the high crystal symmetry of these phosphors makes it possible to provide structured screens and binderless screens.

It has been disclosed that when binderless screens with an alkali halide phosphor are produced it is beneficial to have the phosphor crystal deposited as some kind of piles, needles, tiles, etc. to increase the image quality than can be obtained when using such a

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screen. In, e.g., US-A 4,769,549 it is disclosed that the image quality of a binderless phosphor screen can be improved when the phosphor layer has a block structure shaped in fine pillars. In e.g. US-A 5,055,681 a storage phosphor screen comprising an alkali halide phosphor in a pile-like structure is disclosed. Also in EP-A 1 113 458 a phosphor panel with a vapor deposited CsBr:Eu phosphor layer wherein the phosphor is present as fine needles separated by voids is disclosed for optimising the image quality.

Unfortunately such needle shaped phosphors are quite brittle and the phosphor panels are prone to physical damage after only a few cycles in the scanning apparatus. It has been proposed to strengthen the screens or panels by applying a protective layer on top of the vapor deposited phosphor layer. Such a protective overcoat has been described in EP-A 0 392 474. An intensifying screens having a very useful protective coating of a fluorine-resin and an oligomer, having a polysiloxane structure has been described in EP-A 0 579 016. Also the use of radiation curable coating to form a protective top layer in a X-ray conversion screen has been described e.g. in EP-A 0 209 358, in JP-A 86-176900 and in US-A 4,893,021. For example, the protective layer comprises a UV cured resin composition formed by monomers and/or prepolymers that are polymerized by free-radical polymerization with the aid of a photoinitiator. The monomeric products are preferably solvents for the prepolymers used. Impregnating storage phosphor layers with a polymer material as, e.g., a thermosetting resin, has been disclosed in EP-A 0 288 038.

In EP-A 1 316 969, a binderless stimuable phosphor screen has been disclosed having a support and a vapor deposited phosphor layer and a protective layer on top of said phosphor layer, characterized in that said vapor deposited phosphor is needle shaped and said phosphor needles have a length, L and voids between them and wherein said protective layer fills said void for at most 0.10 times L. By doing so the strength of the panel is increased, as well as by adding polymeric compounds in order to partially fill the voids as described in EP-A 1

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347 460. From 'other' technological fields as e.g. production systems for ceramic products, it has e.g. been learnt that polysilazane-type polymers are advantageously used while these polymers are impregnating e.g. porous ceramics as has been disclosed in US-A 5,459,114; thereby  
5 increasing mechanical strength in ceramic products.

With respect to image quality it has been disclosed in US-A 4,947,046 that the voids between needle phosphors can be filled with colorants, dyes and/or pigments, thus enhancing the said image quality.

Stimulable or storage phosphor materials such as alkali metal  
10 halide phosphors are known to be highly moisture sensitive: absorption of moisture in the surrounding air thereby deteriorates characteristics of the phosphor, and moreover, resolution or image definition.

Therefor a moisture-resistant barrier impermeable to water is highly desired on the upper side of the phosphor layer in order to protect the  
15 phosphor against moisture (and physical damage) as has e.g. been disclosed in US-A 5,466,947 for a stimulable phosphor having a plasma protective thin parylene polymer coating in order not to suppress sensitivity of the phosphor panel for weak radioactive labels. In a radiation detecting apparatus comprising such a moisture sensitive  
20 phosphor layer, present on an imaging device or a fiber optical plate or FOP, known as an optical part constituted by a plurality of optical fibers bundled together so that the radiation incident thereon from the phosphor layer side is converted into light to be detected after stimulation of storage phosphor, protection of phosphor particles and  
25 the layer wherein the said particles are present is highly desired, more particular from the point of view of image definition.

#### OBJECTS AND SUMMARY OF THE INVENTION

30 It is an object of the present invention to provide a stimulable phosphor screen useful in an X-ray recording system resistant to moisture in order to avoid loss in image quality.

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More in particular it is an object of the present invention to provide a binderless stimuable phosphor screen useful for same purposes, wherein said screen is resistant to moisture in order to avoid loss in image quality.

The above mentioned object is realized by providing a stimuable phosphor screen having the specific features defined in claim 1. Specific features for preferred embodiments of the invention are disclosed in the dependent claims.

Further advantages and embodiments of the present invention will become apparent from the following description.

#### DETAILED DESCRIPTION OF THE INVENTION

It has been found that in a storage phosphor panel, and, more particularly, in a binderless stimuable phosphor screen comprising a radiation-transparent substrate and a needle-shaped stimuable phosphor layer formed on said substrate, adequate protection of the said stimuable phosphor screen or panel against environmental air moisture is obtained by providing a first transparent organic film covering said stimuable phosphor layer, and a second outermost transparent film formed on said first transparent organic film, wherein presence as a second transparent film of a silazane or siloxazane type polymer film is particularly suitable. In a preferred embodiment according to the present invention said second transparent film is a polymeric film containing polymers selected from the group consisting of silazane and siloxazane type polymers, mixtures thereof and mixtures of said silazane or siloxazane type polymers with compatible film-forming polymers.

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Siloxazane polymer types, useful therefore have been known since quite a lot of time: so e.g. in US-A 3,271,361 a process for making ordered siloxazane polymers has been described, whereas in GB-A 1,084,659 improvements in or related with organosilicon polymers have been disclosed. Much more recently PCT-filing WO87/05298 has been describing polysilazanes and related compositions, processes and uses. That invention also relates to the use of polysiloxazanes and polyhydridosiloxanes as ceramic precursors. The hardness, strength, structural stability under extreme environmental conditions of those compounds is said to be well-known. Controll of the polysilazane molecular weight, structural composition and viscoelastic properties play a considerable role in determining the tractability (solubility, meltability or malleability) of the polymer, the ceramic yield, and the selectivity for specific ceramic products. In particular, the tractability plays a major role in how useful the polymer is as a binder, or for forming shapes, coatings, spinning fibers and the like. The more cross-linked a polymer is, the less control one has of its viscoelastic properties. Thus, highly cross-linked and low molecular weight polymers are not particularly useful for spinning fibers because the spun preceramic fiber often lacks tensile strength and is therefore unable to support its own weight. By contrast, high molecular weight, substantially linear polymers as provided therein are extremely important. Such polymers represent a significant advance in the art, as they provide chain entanglement interactions in the fiber-spinning process and thus enhance the overall tensile strength of the spun fibers. "Silazanes" are compounds which contain one or more silicon-nitrogen bonds, whereas "polysilazanes" are intended to include oligomeric and polymeric silazanes, i.e. compounds which include two or more monomeric silazane units. "Siloxazanes" are compounds which contain the unit [O--Si--N] and the term "polysiloxazane" is intended to include oligomeric and polymeric siloxazanes, i.e. compounds which include two or more monomeric siloxazane units. Ceramic materials are thus provided as being useful in a number of applications, including as

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coatings for many different kinds of substrates. Silicon nitride and silicon oxynitride coatings may be provided on a substrate, for example, by a variation of the pyrolysis method just described. A substrate selected such that it will withstand the high temperatures of pyrolysis (e.g., metal, glass, ceramic, fibers, graphite) is coated with a preceramic polymer material by dipping in a selected silazane or siloxazane polymer solution, or by painting, spraying, or the like, with such polymer solution, the solution having a predetermined concentration, preferably between about 0.1 and 100 wt.%, more preferably between about 5 and 10 wt.% for most applications. The liquid or dissolved polymer may be admixed with ceramic powders such as silicon nitride or silicon carbide optionally admixed with sintering aids such as aluminum oxide, silica, yttrium oxide, and the like, prior to coating. Cross-linking agents may be included in the coating mixture as well, as e.g. siloxane oligomers or polymers such as  $[\text{CH}_3\text{SiHO}]_x$  can be reacted with ammonia or amine to introduce nitrogen moieties into these species. These reactions may lead to the formation of a nitrogen cross-linked polymer having a homogeneous distribution of Si--O and Si--N bonds in the polymer. The siloxazane so provided may be pyrolysed under an inert gas such as nitrogen or argon, or under ammonia or a gaseous amine compound, to yield ceramic mixtures containing silicon oxynitride. Alternatively, nitrogen-free siloxane starting materials which may be oligomeric or polymeric are pyrolyzed under ammonia or a gaseous amine atmosphere to give silicon oxynitride directly. In this case, the nitrogen is introduced into the siloxane during rather than prior to pyrolysis. The siloxane may be a sesquisiloxane, a polyhydridosiloxane, a cross-linked polysiloxane or a polysiloxane with latent reactive groups such as hydrogen amine, alkoxy, sulfide, alkenyl, alkynyl, etc., which can be cross-linked during heating or replaced during curing. The procedure described in the cited PCT-filing for producing coatings containing silicon nitride can be done with a conventional furnace.

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Further, the method leads to heat-stable, wear-, erosion-, abrasion, and corrosion-resistant silicon nitride ceramic coatings. Because silicon nitride is an extremely hard, durable material, many applications of the coating process are possible. Preceramic polymers as provided, admixed with ceramic powders, may be used to form three-dimensional articles by injection- or compression-molding. Preceramic polymer/ceramic powder system is advantageously used to form three-dimensional bodies by compression molding.

In another application substantially linear high molecular polysilazanes in particular, can be used for preceramic fiber spinning. Infiltration and impregnation processes are further possibilities, as discussed, e.g., in US-A 4,177,230 and in W. S. Coblenz et al. in "Emergent Process Methods for High-Technology Ceramics", Ed. Davis et al. (Plenum Publishing, 1984). Two general methods are typically used. One is a high-vacuum technique in which a porous ceramic body is contacted under vacuum with a liquid or dissolved preceramic polymer. After a high vacuum infiltration, the article is pyrolyzed to achieve a higher density. The second method is high-pressure infiltration. In addition, low molecular weight oligosilazane solutions having higher mobility in the porous ceramic body can be incubated with the ceramic body and a transition metal catalyst, followed by curing of the oligomeric reactants. In situ chain extension or cross-linking will reduce the mobility and volatility of the oligomeric starting materials.

As has been set forth in US-A 5,459,114 polysilazane, prepared therein like for example, an inorganic polysilazane, an inorganic polysiloxazane, a polyorgano(hydro)silazane, a modified polysilazane or a polymetallosilazane, by performing chemical vapor deposition (CVD) coating before or after said process of impregnation, curing and firing, makes delamination of fibers to be minimized.



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Novel polysiloxazanes comprising  $[(\text{SiH}_2)_n \text{NH}]$  and  $[(\text{SiH}_2)_m \text{O}]$  as the main repeating units are provided in US-A 4,869,858, wherein it was an object to provide a simple process for producing continuous silicon oxynitride fibers. The polysiloxazanes are produced by reacting a dihalosilane or an adduct thereof with a Lewis base, with ammonia and water vapor or oxygen. From the polysiloxazane, novel silicon oxynitride shapes can be produced and the silicon oxynitride shapes are essentially composed of silicon, nitride (5 mol % or more) and oxygen (5 mol % or more).

More recently in US-A 6,210,786 a fiber-reinforced ceramic matrix composite (FRCMC) structure having tailored physical properties has been provided, with a polymer-derived ceramic resin in its ceramic form and with fibers in a sufficient quantity incorporated within the ceramic resin, in order to produce a desired degree of ductility exhibited by the structure, wherein the degree of ductility exhibited varies with the percentage by volume of the fibers, with said fibers having thereon an interface coating different from the composite and residing on the fibers between the fibers and the composite.

As has been disclosed even more recently in US-A 6,368,663 there is provided a ceramic-based composite member comprising a dense matrix formed on a surface of a shaped fabric, and a matrix having fine cracks formed in a gap of the matrix. In the structure, since the binding force of the ceramic fiber by the matrix having fine cracks is weak, a kind of soft structure is formed, Young's modulus is lowered, the thermal stress is reduced, and the resistance to thermal shock is enhanced. Moreover, according to that invention, there is provided a method of manufacturing a ceramic-based composite member, in which after CVI (Chemical Vapor Infiltration) treatment is performed to form an SiC matrix on a surface of a shaped fabric, PIP (Polymer Impregnation and Pyrolysis) treatment is performed to infiltrate a gap of the dense matrix with an organic silicon polymer as a base before

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performing pyrolysis'. The method of that invention is a process (hereinafter referred to as the hybrid treatment) constituted by combining CVI and PIP treatments, a dense matrix is formed around a ceramic fiber by CVI treatment, and the gap is infiltrated/filled with the matrix by the PIP treatment. Additionally, the matrix formed by the hybrid treatment is called the hybrid matrix. The PIP (Polymer Impregnation and Pyrolysis) treatment has a faster matrix forming rate as compared with CVI treatment, and can repeatedly be performed in a short time. Therefore, by repeating the PIP treatment, the gap after the CVI treatment is filled well, and the hermetic properties can be enhanced.

Providing a carbon/carbon composite comprising crystalline silicon carbide which is essentially uniformly distributed on both internal and external surfaces of the composite in a low concentration, as well as a process for producing the composite and the use of the composite has been described in US-A 6,376,431; wherein it has been discovered that small amounts of crystalline silicon carbide uniformly distributed throughout the carbon/carbon composite results in reduced wear with either no change or a slight increase in the friction coefficient.

The phosphor layer generally comprises a binder and a stimuable phosphor dispersed therein. However, there is also known a phosphor layer comprising agglomerate of a stimuable phosphor without binder. The phosphor layer containing no binder can be formed by deposition process or firing process. Further, there is known a phosphor layer comprising agglomerate of a stimuable phosphor impregnated with a polymer material. A radiation image storage panel having any of the above phosphor layers can be used for the radiation image recording and reproducing method.

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The phosphor layer can be formed by coating a dispersion containing phosphor particles and a binder polymer in a proper organic solvent. In the coating dispersion, the binder polymer and the stimuable phosphor particles are contained generally in a ratio in the range of 1:1 to 1:100 (binder:phosphor, expressed by weight), preferably 1:8 to 1:50 (by weight). As the binder polymer, a variety of resins are known and are employable for the present invention. The dispersion may be coated on the permanent support to directly form the phosphor layer. Otherwise, it may be coated on a temporary support to form a sheet for the phosphor layer, and then the formed sheet is peeled from the temporary support and stuck on the permanent support. In that case, the sheet for the phosphor layer may be pressed under heating in the known manner. The thickness and the material of the support are also known and they can be optionally determined. Auxiliary layers such as a subbing layer and a light-reflecting layer may be provided on the support. The thickness of the phosphor layer is generally in the range of 20  $\mu\text{m}$  to 1 mm, preferably 50 to 500  $\mu\text{m}$ . The procedure comprising the steps of peeling the protective film from the continuous multi-layer sheet (comprising a coated, e.g. fluoro-resin, layer, transparent resin film, adhesive layer, and protective layer) and sticking the multi-layer sheet on the phosphor sheet can be carried out in the system wherein the continuous multi-layer sheet is wound around a roll. Immediately after the continuous sheet is drawn out from the roll, the protective film is peeled off by means of the separator rolls and then a continuous sheet becomes superposed on the phosphor sheet so that the bared surface may be in contact with the surface of the phosphor layer. Subsequently, the continuous multi-layer sheet and phosphor sheet are passed together through the laminate rolls so that both sheets are fixed to each other. In the case that the protective film is also provided on the coated layer, the film is peeled off after the above laminating step. In the above described continuous multi-layer sheet preparation method, comprising adhesive layer, transparent resin film layer and coated resin layer provided, in this order, on the

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phosphor layer of phosphor sheet, the multi-layer sheet is cut into pieces of the predetermined size to give the desired radiation image storage panel.

5 In case of a binderless phosphor layer and preparation of the said layer by "vapor deposited phosphor" it is further, throughout this text, meant that a phosphor is deposited on a substrate by any method selected from the group consisting of thermal vapor deposition, chemical vapor deposition, electron beam deposition, radio frequency  
10 deposition and pulsed laser deposition. This vapor deposition is preferably carried out under conditions as described in EP-A-1 113 458. When vapor deposited phosphor layers contain phosphor needles separated by voids as disclosed in, e.g., EP-A-1 113 458, the phosphor layer is, as said above, quite sensitive for environmental moisture.

15

It has been found now that, according to the present invention the stimuable phosphor screen, covered above a first transparent organic film layer with a second transparent film formed on said first transparent organic silazane or siloxazane type polymeric film,  
20 provides an excellent and efficient protection of the screen or panel against moisture present in the environment. Said second transparent film as a polymeric film thus contains polymers selected from the group consisting of silazane and siloxazane type polymers, mixtures thereof and mixtures of said silazane or siloxazane type polymers with  
25 compatible film-forming polymers.

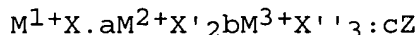
The selected silazane or siloxazane type polymeric compounds can be dissolved in any suitable solvent, e.g., alcohols such as methanol, ethanol, n-propanol, methoxypropanol and n-butanol; chlorinated  
30 hydrocarbons such as methylene chloride and ethylene chloride; ketones such as acetone, butanone, methyl ethyl ketone, diethyl ketone and methyl isobutyl ketone; esters of alcohols with aliphatic acids such as methyl acetate, ethyl acetate and butyl acetate; ethers such as

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dioxane, ethylene glycol monoethylether; methyl glycol; aromatic hydrocarbons such as toluene and mixtures of the above-mentioned solvents.

5 The storage phosphor in a binderless storage phosphor screen according to the present invention may be any storage phosphor known in the art. Preferably the storage phosphor in such a binderless storage phosphor screen is an alkali metal phosphor.

10 Suitable phosphors are, e.g., phosphors according to formula I:



wherein:

$M^{1+}$  is at least one member selected from the group consisting of Li, Na, K, Cs and Rb,

15  $M^{2+}$  is at least one member selected from the group consisting of Be, Mg, Ca, Sr, Ba, Zn, Cd, Cu, Pb and Ni,

$M^{3+}$  is at least one member selected from the group consisting of Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Al, Bi, In and Ga,

20 Z is at least one member selected from the group  $Ga^{1+}$ ,  $Ge^{2+}$ ,  $Sn^{2+}$ ,  $Sb^{3+}$  and  $As^{3+}$ ,

X, X' and X'' can be the same or different and each represents a halogen atom selected from the group consisting of F, Br, Cl, I and  $0 \leq a \leq 1$ ,  $0 \leq b \leq 1$  and  $0 < c \leq 0.2$ .

25 Such phosphors have been disclosed, e.g., in US-A-5 736 069.

Highly preferred storage phosphors for use in a binderless phosphor screen of the present invention are  $CsX:Eu$  stimulable  
30 phosphors, wherein X represents a halide selected from the group consisting of Br and Cl and combinations thereof prepared by a method comprising the steps of

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- mixing said CsX with between  $10^{-3}$  and 5 mol % of a Europium compound selected from the group consisting of  $\text{EuX}'_2$ ,  $\text{EuX}'_3$  and  $\text{EuOX}'$ , X' being a member selected from the group consisting of F, Cl, Br and I,
- firing said mixture at a temperature above 450 °C
- 5 - cooling said mixture and
- recovering the CsX:Eu phosphor.

In a most preferred embodiment according to the present invention in the stimuable phosphor screen or panel the said phosphor is a  
10 needle-shaped vapor-deposited CsBr:Eu phosphor. As the phosphor screen comprises a vapor deposited CsBr:Eu needle phosphor it is preferred to use polymers that do not carry hydrophilic, moisture attracting substituents. The selected silazane or siloxazane type polymeric compounds for use as an outermost film onto the phosphor screen with a  
15 vapor deposited CsBr:Eu needle phosphor are preferably dissolved in a solvent that can easily be kept water free, wherein by water free is understood a solvent that has less than 1 % wt/wt of water.

It is further not excluded to additionally bring a silazane or  
20 siloxazane type polymeric compound in the voids between the needle phosphors in a vapor deposited phosphor screen of the present invention before applying a protective layer on top of the phosphor layer. So a solution having a viscosity in order to provoke seeping of the coating solution into the voids between the phosphor needles may be applied in  
25 that case. When filling the voids it is thus preferred that the viscosity of the coating solution is adapted so that, with phosphor needles having a length, L, said protective layer fills said void for at most 0.10 times L or 10 % of L. When the voids are filled deeper ease of recycling the phosphor is questionable. It has been found now  
30 that by adjusting the viscosity of the protective layer so that, with phosphor needles having a length, L, filling said voids for at most 0.10 times L, is a most acceptable compromise between strength of the

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phosphor layer and ease of recycling or recuperation of the phosphor is achievable.

Although the image quality that can be obtained in computed  
5 radiography when using a stimuable phosphor panel of the present  
invention having needle shaped phosphor is very high, it has been found  
that the image quality is further enhanced when the voids between the  
phosphor needles moreover contain a colorant, i.e., a dye or pigment  
that absorbs light of the stimulating wavelength. A further improvement  
10 has been realized when the voids are containing a colorant absorbing  
the stimulating radiation together with a colorant reflecting the light  
emitted by the stimuable phosphor upon stimulation. When an alkali  
metal phosphor is used in the panel according to the present invention,  
then the stimulating light is either red or infrared light and then the  
15 colorant is preferably a blue colorant. As the colorant, either an  
organic colorant or an inorganic colorant can be employed. So an  
organic colorant having a body color ranging from blue to green  
suitable for use in the radiation image storage panel of the present  
invention includes ZAPON FAST BLUE 3G (manufactured by Hoechst AG.),  
20 ESTROL BRILL BLUE N-3RL (manufactured by Sumitomo Kagaku Co., Ltd.),  
SUMIACRYL BLUE F-GSL (manufactured by Sumitomo Kagaku Co., Ltd.), D & C  
BLUE No. 1 (manufactured by National Aniline Co., Ltd.), SPIRIT BLUE  
(manufactured by Hodogaya Kagaku Co., Ltd.), OIL BLUE No. 603  
(manufactured by Orient Co., Ltd.), KITON BLUE A (manufactured by Ciba  
25 Geigy AG.), AIZEN CATHILON BLUE GLH (manufactured by Hodogaya Kagaku  
Co., Ltd.), LAKE BLUE A.F.H. (manufactured by Kyowa Sangyo Co., Ltd.),  
RODALIN BLUE 6GX (manufactured by Kyowa Sangyo Co., Ltd.), PRIMOCYANINE  
6GX (manufactured by Inahata Sangyo Co., Ltd.), BRILLACID GREEN 6BH  
(manufactured by Hodogaya Kagaku Co., Ltd.), CYANINE BLUE BNRS  
30 (manufactured by Toyo Ink Co., Ltd.), LIONOL BLUE SL (manufactured by  
Toyo Ink Co., Ltd.), and the like. E.g., an inorganic colorant having  
a body color ranging from blue to green which is advantageously  
employed in the radiation image storage panel of the present invention

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includes ultramarine blue, cobalt blue, cerulean blue. Other useful colorants are the blue colorants sold by BASF AG of Germany under the trade name HELIOGEN BLUE and those sold by Bayer AG of Germany under trade name MACROLEX BLUE.

5

The colorant, contained in the voids of a panel of the present invention, intended for reflecting the emitted light, preferably is a white pigment. Very suitable white pigments are, e.g.,  $\text{TiO}_2$ ,  $\text{ZnS}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ , and  $\text{BaSO}_4$ , without however being limited thereto.  $\text{TiO}_2$  in  
10 its anatase crystal form is a preferred white pigment for use in a panel of the present invention.

The colorant(s) can be brought in the voids either before adding e.g. silazane or siloxazane type polymeric compound, as described  
15 hereinbefore, or together with the said silazane or siloxazane type polymeric compounds. When the colorant is brought into the voids before the polymeric compound, then the compound can be introduced into the fine gaps whose width is preferably 1-30  $\mu\text{m}$ . The substance of fine particles having a diameter of several hundred nanometers may be  
20 introduced physically without previous processing. When the substance has a lower melting point, it may be heated and introduced. The substance may be permeated into the gap when dissolved or dispersed in a liquid having suitable viscosity and is deposited by evaporation or modification by heating. The substance may be introduced into the gap  
25 by a gas phase deposition method. In the latter case a suitable pigment can be a dye as used in thermal dye sublimation transfer. Typical and specific examples of dyes for use in thermal dye sublimation transfer have been described e.g. in EP-A's 0 209 990, 0 209 991, 0 216 483, 0 218 397, 0 227 095, 0 227 096, 0 229 374, 0  
30 235 939, 0 247 737, 0 257 577, 0 257 580, 0 258 856, 0 400 706, 0 279 330, 0 279 467 and 0 285 665, US-A-4 743 582, US-A-4 753 922, US-A-4 753 923, US-A-4 757 046, in US-A's 4,769,360; 4,771,035 and 5,026,677; in JP-A's 84/78894, 84/78895, 84/78896, 84/227490,



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84/227948, 85/27594, 85/30391, 85/229787, 85/229789, 85/229790,  
85/229791, 85/229792, 85/229793, 85/229795, 86/41596, 86/268493,  
86/268494, 86/268495 and JP-A-86/284 489. When the colorants are not  
introduced by gas phase deposition in the voids between the phosphor  
5 needles, then colorants can, for application in the voids of a phosphor  
panel of the present invention, be dissolved or dispersed in any  
suitable solvent. Hereinafter the term "solution(s) of a colorant" is  
used to include both solution and dispersions. Examples of suitable  
solvents are, e.g., lower alcohols such as methanol, ethanol,  
10 n-propanol and n-butanol; chlorinated hydrocarbons such as methylene  
chloride and ethylene chloride; ketones such as acetone, butanone,  
methyl ethyl ketone and methyl isobutyl ketone; esters of lower  
alcohols with lower aliphatic acids such as methyl acetate, ethyl  
acetate and butyl acetate; ethers such as dioxane, ethylene glycol  
15 monoethyl ether; methyl glycol; and mixtures of the above-mentioned  
solvents. When the phosphor screen comprises the preferred vapor  
deposited CsBr:Eu needle-shaped phosphor, it is preferred to use  
solvents that can easily be kept water free as already suggested  
hereinbefore. The expression "water free" means that a solvent that  
20 less than 1 % wt/wt of water. Therefore esters of lower alcohols with  
lower aliphatic acids such as methyl acetate, ethyl acetate and butyl  
acetate and toluene are preferred solvents.

When the colorants are dispersed in the solution it is preferred  
25 that the average particle size of the colorant is adapted to the width  
of the voids. It is known from US-A 4,947,046, that the voids between  
phosphor needles are e.g. between 0.01  $\mu\text{m}$  and 30  $\mu\text{m}$ .

In a preferred embodiment of the present invention, the polymeric  
30 solution for filling the voids further contains one or more colorant(s)  
so that in one step both the elasticity of the screen and the image  
quality can be increased by adding simultaneously a polymer and at  
least one colorant in the voids.

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The stimuable phosphor screen according to the present invention thus comprises a radiation-transparent substrate; a (preferably needle-shaped) stimuable phosphor layer formed on said substrate; a first  
5 transparent organic film covering said stimuable phosphor layer; and a second transparent film formed on said first transparent organic film, characterized in that said second transparent film is a polymeric film containing polymers selected from the group consisting of silazane and  
10 siloxazane type polymers, mixtures thereof and mixtures of said silazane or siloxazane type polymers with compatible film-forming polymers.

In another embodiment said stimuable phosphor screen according to the present invention further comprises an intermediate transparent  
15 organic film between said substrate and said stimuable phosphor layer.

In a preferred embodiment according to the present invention said organic film, whether being present alone as first organic film, whether present as an intermediate layer together with that first  
20 organic film in the layer arrangement of the stimuable phosphor screen, is a "parylene" film, i.e. a poly-paraxylylene film.

Preferred polymers for use as organic "parylene" film are poly(p-xylylene), poly(p-2-chloroxylylene), poly(p-2,6-dichloroxylylene) and  
25 fluoro substituted poly(p-xylylene). Most preferred polymers for use in the protective layer of this invention are vacuum deposited, preferably chemical vacuum deposited poly-p-xylylene film. A poly-p-xylylene has repeating units in the range from 10 to 10000, wherein each repeating unit has an aromatic nuclear group, whether or not  
30 substituted. Each substituent group, if present, can be the same or different and can be any inert organic or inorganic group which can normally be substituted on aromatic nuclei. Illustrations of such substituent groups are alkyl, aryl, alkenyl, amino, cyano, carboxyl,

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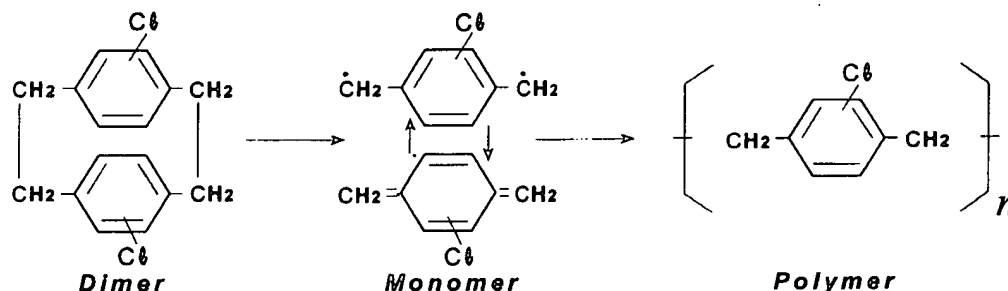
alkoxy, hydroxylalkyl, carbalkoxy and similar groups as well as inorganic ions such as hydroxyl, nitro, halogen and other similar groups which are normally substitutable on aromatic nuclei. Particularly preferred substituted groups are those simple hydrocarbon groups such as the lower alkyl groups such as methyl, ethyl, propyl, butyl, hexyl and halogen groups particularly chlorine, bromine, iodine and fluorine as well as the cyano group and hydrogen.

As a basic agent the commercially available di-p-xylylene composition sold by the Union Carbide Co. under the trademark "PARYLENE" is thus preferred. The preferred compositions for the protective moistureproof protective layer covering the phosphor screens or panels thus are the unsubstituted "PARYLENE N", the monochlorine substituted "PARYLENE C", the dichlorine substituted "PARYLENE D" and the "PARYLENE HT" (a completely fluorine substituted version of PARYLENE N, opposite to the other "parylenes" resistant to heat up to a temperature of 400°C and also resistant to ultra-violet radiation, moisture resistance being about the same as the moisture resistance of "PARYLENE C": see the note about "High Performance Coating for Electronics Resist Hydrocarbons and High Temperature" written by Guy Hall, Specialty Coating Systems, Indianapolis, available via [www.scscookson.com](http://www.scscookson.com). Technology Letters have also been made available by Specialty Coating Systems, a Cookson Company, as e.g. the one about "Solvent Resistance of the parylenes", wherein the effect of a wide variety of organic solvents on parylenes N, C, and D was investigated.

Most preferred polymers for use in the preparation of the organic polymer film layer as set forth hereinbefore are poly(p-2-chloroxylylene), i.e. PARYLENE C film, poly(p-2,6-dichloroxylylene), i.e. PARYLENE D film and "PARYLENE HT" (a completely fluorine substituted version of PARYLENE N).

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Parylene is available from a variety of sources and is commonly used for protecting printed circuit boards, sensors, and other electronic and electrical devices. Although the specific manner in which the parylene is applied as a layer covering the phosphor layer or, moreover as intermediate layer between radiation-transparent substrate and phosphor layer forms no part of the present invention, it is preferred to apply the parylene layer by chemical vapor deposition (CVD). A method for doing so is disclosed in EP-A 1 286 364. The process of deposition basically proceeds as follows :



A suitable dimer, - e.g., (cyclo-di(p-xylene) for the deposition of PARYLENE N, cyclo-di(p-2-chloroxylylene) for the deposition of PARYLENE C or cyclo-di(p-2,6-dichloroxylylene) for the deposition of PARYLENE D), - is heated and decomposes in two radicals. These radicals are deposited on the phosphor layer where they polymerize and form a polymeric layer. The chemical vapor deposition of the parylene layer (either PARYLENE N, C or D) has several advantages as the layer is deposited without pinholes and as the barrier layer is not only deposited on the main surface of the phosphor layer, but also on the edges so that the sealing of the phosphor layer is complete.

Preferably the parylene layer(s) have a thickness in the range between 0.05  $\mu\text{m}$  and 15  $\mu\text{m}$ , more preferably between 1  $\mu\text{m}$  and 10  $\mu\text{m}$ .

According to the present invention the stimuable phosphor screen has, as a radiation-transparent substrate, an aluminum or an amorphous

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carbon (a-C) substrate. Such an aluminum or an amorphous carbon film substrate, preferably present onto a polymeric support opens perspectives in order to produce a binderless storage phosphor screen on a support with low X-ray absorption, even if the storage phosphor layer is applied by vacuum deposition at fairly high temperatures. Amorphous carbon (a-C) films suitable for use in this invention are commercially available through, e.g., Tokay Carbon Co, LTD of Tokyo, Japan or Nisshinbo Industries, Inc of Tokyo, Japan, where they are termed "Glass-Like Carbon Film", or "Glassy Carbon".

In a binderless phosphor panel or screen according to the present invention, the thickness of the amorphous carbon layer may range from 100  $\mu\text{m}$  up to 3000  $\mu\text{m}$ , a thickness between 500  $\mu\text{m}$  and 2000  $\mu\text{m}$  being preferred as compromise between flexibility, strength and X-ray absorption.

The need for very high mechanical strength as is especially desired in the radiographic systems wherein use is made of a storage phosphor panel wherein during reading of the energy stored in the panel, the panel is automatically removed from the cassette, moved through a reader, often via a sinuous path, and then put back in the cassette. In such a reader it is quite advantageous to make use of a screen or panel with an auxiliary layer laminated on the amorphous carbon layer or aluminum layer: this auxiliary polymer support layer can be any polymeric film known in the art, e.g. polyester film, polyvinylchloride, polycarbonate, syntactic polystyrene, etc.. Preferred polymeric films are polyester ester films, as e.g., polyethylene terephthalate films, polyethylene naphthalate films, etc.. The thickness of the auxiliary layer may range from 1  $\mu\text{m}$  to 500  $\mu\text{m}$ . It is possible to use a fairly thin amorphous carbon film, e.g., 400  $\mu\text{m}$  and laminate a 500  $\mu\text{m}$  thick polymeric film to it as well as to use a thick amorphous carbon film, e.g., 2000  $\mu\text{m}$  thick with a thin, e.g., 6  $\mu\text{m}$  thick, polymeric film laminated onto it. The relative thickness of

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the amorphous carbon or aluminum layer on one hand, and the polymeric support film at the other hand, may be varied widely and is only directed by the required physical strength of the amorphous carbon or aluminum during deposition of the phosphor layer and the required flexibility during use of the panel.

Presence of a radiation-transparent substrate, optionally coated with a moisture-resistant parylene layer, a binderless storage phosphor layer formed thereupon (preferably being a binderless needle-shaped, vapor-deposited CsBr:Eu phosphor in the stimulable phosphor screen according to the present invention), a first transparent organic film, preferably a moisture-resistant parylene layer covering over the storage phosphor layer, and a transparent inorganic film formed on the first transparent organic film, wherein said second transparent film is a silazane or siloxazane type polymeric film provides a remarkably improved protection against moisture from environmental air to the screen or panel.

The radiation image storage panel of the present invention is thus, in a preferred embodiment, characterized in that it comprises a radiation-transparent substrate (wherein radiation transparency is particularly desired for mammographic applications), a binderless needle-shaped storage phosphor formed on the substrate, optionally with an intermediate layer between substrate and phosphor layer, a first transparent organic film (preferably a "parylene" layer, preferably - not being limited thereto - having the same composition as the intermediate layer - if said intermediate layer is present), covering over the storage phosphor layer, a transparent inorganic film of polysilazanes or polysiloxazanes formed on the first transparent organic film, and an imaging device disposed in order to face the storage phosphor screen. Such a layer arrangement as disclosed above effectively provides an excellent moisture resistance and scratch resistance of the normally moisture-sensitive and scratch-sensitive

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phosphor layer, and, as a consequence preserves image quality in an efficient way.

A radiation image sensor of the present invention thus comprises  
5 a stimuable phosphor screen as described before, and  
an imaging device disposed in order to face said stimuable phosphor  
screen. In a preferred embodiment according to the present invention a  
radiation image sensor comprises a stimuable phosphor screen and  
an imaging device disposed in order to face said stimuable phosphor  
10 screen. According to the present invention, in a preferred embodiment  
thereof, said imaging device is a CCD.

The method of producing or preparing such a storage phosphor  
panel of the present invention is further characterized in that it  
15 comprises steps of forming a binderless needle-shaped, vapor-deposited  
CsBr:Eu phosphor layer on a radiation-transparent substrate, forming a  
first transparent organic film covering over the storage phosphor  
layer, and forming a transparent inorganic film on the first  
transparent organic film. Optionally an intermediate film, preferably  
20 having the same composition as the first transparent organic film, in  
order to produce a radiation image storage screen or panel in which the  
moisture resistance of the phosphor layer is remarkably improved. It  
is clear that the layers as defined herein are, in a preferred  
embodiment the same preferred layers as described before.

25

According to the present invention a method of preparing or  
manufacturing a stimuable phosphor screen or panel is further offered,  
wherein said screen is characterized by the specific features as  
disclosed hereinbefore, said method comprising the steps of:

- 30 - forming a stimuable phosphor layer on a radiation-transparent  
substrate;  
- forming a first transparent organic film covering over said needle-  
shaped stimuable phosphor layer; and

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- forming a second transparent film formed on said first transparent organic film, wherein said second transparent film is a polymeric film containing polymers selected from the group consisting of silazane and siloxazane type polymers, mixtures thereof and mixtures of said  
5 silazane or siloxazane type polymers with compatible film-forming polymers.

In a preferred embodiment of the manufacturing methods disclosed above said organic film is a poly-paraxylylene film.

10

The method of producing a radiation image storage panel according to the present invention, in a particular embodiment, is characterized in that it comprises the steps of forming the (preferably vapor deposited needle-shaped) storage phosphor layer on a radiation-  
15 transparent substrate, whether or not covered with a transparent organic film (preferably a parylene film), forming a first transparent organic film (also having parylene composition) covering over the storage phosphor panel and forming a transparent inorganic film on the first transparent organic film characterized in that said second  
20 transparent film is a silazane or siloxazane type polymeric film; further disposing an imaging device opposite the storage phosphor layer.

Since the transparent inorganic film is formed on the first  
25 transparent organic film, the present invention provides manufacturing of a radiation image sensor in which the moisture resistance of storage phosphor panel is remarkably improved.

According to the present invention a method of preparing a  
30 stimuable phosphor screen or panel is provided, said method comprising the steps of:

- forming a needle-shaped stimuable phosphor layer on a radiation-transparent substrate;



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- forming a first transparent organic film covering over said needle-shaped stimuable phosphor layer; and
- forming a transparent inorganic film on said first transparent organic film, wherein said second transparent inorganic film is a  
5 silazane or siloxazane type polymeric film.

The invention further encompasses a method for producing a binderless needle-shaped stimuable phosphor layer on a radiation-transparent substrate, wherein said method comprises the steps of :

- 10 - vapor depositing a photostimulable phosphor on a substrate forming a phosphor layer with phosphor needles and voids between them,
- applying a solution of a polymer on said vapor deposited phosphor,
- optionally wiping (not required in case of dip-coating, spray-coating, bar-coating and sieve coating) the excess of said solution  
15 from said phosphor layer and
- drying the phosphor screen.

The invention also encompasses a method for producing a binderless needle-shaped stimuable phosphor layer on a radiation-transparent substrate containing a CsX:Eu stimuable phosphor, wherein  
20 X represents a halide selected from the group consisting of Br, Cl and combinations thereof comprising the steps of :

- bringing multiple heatable containers of CsX and a Europium compound selected from the group consisting of  $\text{EuX}'_2$ ,  $\text{EuX}'_3$  and  $\text{EuOX}'$ ,  
25 X' being selected from the group consisting of F, Cl, Br, I and combinations thereof together with the substrate in a deposition chamber that is evacuated to at least  $10^{-1}$  mbar,
- depositing, by a method selected from the group consisting of physical vapor deposition, chemical vapor deposition or atomization  
30 technique, both said CsX and said Europium compound on a substrate in such a ratio that on said substrate a CsX phosphor, doped with between  $10^{-3}$  and 5 mol % of Europium, is formed

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- applying a solution of a silazane or siloxazane type polymeric compound on said vapor deposited phosphor, and
- drying the phosphor screen.

5       The present invention further, more particularly, encompasses a method for producing a binderless needle-shaped stimuable phosphor layer on a radiation-transparent substrate, said phosphor layer containing a CsX:Eu stimuable phosphor, wherein the method comprises the steps of :

- 10   - bringing a heatable container with a CsX:Eu phosphor, X being selected from the group consisting of Cl, Br and combinations thereof together with the substrate in a deposition chamber that is evacuated to at least  $10^{-1}$  mbar,
- depositing, by a method selected from the group consisting of
- 15   physical vapor deposition, chemical vapor deposition or atomization technique, said CsX:Eu phosphor forming a vapor deposited phosphor layer with needle shaped phosphor,
- applying a solution of a silazane or siloxazane type polymeric compound on said vapor deposited phosphor,
- 20   and
- drying the phosphor screen.

     The storage phosphor panel according to the present invention may further comprise a second transparent organic film formed on the

25   transparent inorganic film of the storage phosphor panel. In that case the second transparent organic film (preferably again a parylene film, but not limited thereto) formed on the transparent inorganic polysilazane or polysiloxazane film may prevent the transparent inorganic film from peeling, more particularly if, apart from the

30   polysilazane or polysiloxazane, inorganic particles are present as e.g. selected from the group consisting of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, In<sub>2</sub>O<sub>3</sub>, SnO<sub>2</sub>, MgO, SiN, MgF<sub>2</sub>, LiF, CaF<sub>2</sub>, and SiNO.

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As the first transparent organic film, preferably having the same composition as the optionally present intermediate layer may cover the whole substrate after having been, in a preferred embodiment as for  
5 parylene, vapor-deposited, an excellent protection of the storage phosphor layer from moisture is provided.

The present invention will become more fully understood from the further detailed description given hereinafter which is given by way of  
10 illustration only, and thus are not to be considered as limiting the present invention.

Further scope of applicability of the present invention will become apparent to those skilled in the art from the description given  
15 hereinbefore and from the further description hereinafter, but it should be understood that specific descriptions, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention.

20

One surface of a substrate made of aluminum in the storage phosphor panel is preferably formed with a storage phosphor having a columnar structure adapted to convert incident radiation into visible light. Eu-doped CsBr is therefor preferably used in that layer.

25

All surfaces of the storage phosphor formed on the said aluminum substrate, together with the substrate itself, are covered with a first poly-paraxylylene film (first transparent organic film), whereas the surface of first polyparaxylylene film on the phosphor layer side is formed with polysiloxazane film (transparent inorganic film).

30

The radiation image sensor, on the other hand, has a structure in which an imaging device is attached to the storage phosphor panel on the storage phosphor.

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Preferred steps of making the storage phosphor panel proceed as follows: on one surface of the aluminum substrate (having a thickness of 1.0 mm), columnar crystals of CsBr doped with Eu are grown by vapor deposition method, in order to form the storage phosphor layer. CsBr:Eu forming the storage phosphor layer is high in moisture absorbency so that it will deliquesce by absorbing vapor in the air if exposed to it without protection. In order to prevent the moisture-sensitive layer from desintegration, the first poly-paraxylylene film is formed by chemical vapor deposition (CDV) technique. Therefor the aluminum substrate whereupon the needle-shaped phosphor has been deposited before, is put into a CVD apparatus, and the first polyparaxylylene film is formed in order to get a thickness of 10  $\mu$ m. As a consequence, the first poly-paraxylylene film is formed over all surfaces of the stimuable needle-shaped phosphor layer and aluminum substrate (at its side, free from columnar needle-shaped phosphor). Since the tip portion of the columnar needle-shaped storage phosphor is uneven, the first polyparaxylylene film also acts as a flattening layer for the tip portion of the said columnar needle-shaped storage phosphor layer.

Subsequently a polysiloxazane film is formed with a thickness of about 10  $\mu$ m by spraying on the first poly-paraxylylene film on the storage phosphor side. Since it is an object for the polysiloxazane film to improve the scratch resistance of the storage phosphor layer, it is formed in an area covering the storage phosphor layer. When this step is performed, the manufacturing of the storage phosphor is completed.

The radiation image sensor is further manufactured by attachment of e.g. a CCD as the imaging device at the side of the storage phosphor layer side of the phosphor panel.

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It is clear that, although a substrate made of aluminum has been used as a substrate in the above-mentioned preferred embodiment, any substrate may be used as long as it has a favorable X-ray transmissivity, whereby substrates made of amorphous carbon (a-C),  
5 substrates made of graphite carbon, substrates made of Be, substrates made of SiC, and the like may also be used.

Further although the polysiloxazane film is formed on the surface of first poly-paraxylylene film on the storage phosphor side in the  
10 above-mentioned embodiment, it is advantageously formed not only at the said surface side of the storage phosphor panel, but also over the whole surface of the first poly-paraxylylene film.

In the above-mentioned embodiments, poly-paraxylylene used as  
15 preferred organic film layer according to the present invention, not only encompasses poly-paraxylylene but also poly-monochloroparaxylylene, poly-dichloroparaxylylene, poly-tetrachloroparaxylylene, poly-fluoroparaxylylene, poly-dimethylparaxylylene, and poly-diethylparaxylylene, without being limited thereto.

20 According to the present invention a method comprising an additional step of forming a third transparent film layer is set forth, wherein said third transparent film layer is a polymeric film covering said second transparent film layer. Moreover in a further embodiment  
25 of the present invention, in order to get thicker topcoat layers, said third transparent film layer is a polymeric film layer containing polymers selected from the group consisting of silazane and siloxazane type polymers, mixtures thereof and mixtures of said silazane or siloxazane type polymers with compatible film-forming polymers.

30 Since the storage phosphor panel of the present invention has a transparent inorganic film formed on the first transparent organic film covering over the storage phosphor panel, the moisture resistance of

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the storage phosphor layer can remarkably be improved by coating one or more transparent inorganic film thereupon.

5 In the case wherein an outermost organic film is further formed on the transparent inorganic film layer or layers, this transparent organic film may prevent the transparent inorganic film from peeling after frequent use.

10 While the present invention will hereinafter be described in the examples in connection with preferred embodiments thereof, it will be understood that it is not intended to limit the invention to those embodiments.

15 EXAMPLES

Preparation of the phosphor screens

CsBr:Eu phosphor screen layers were coated by thermal vapor deposition of CsBr and EuOBr.

20 Therefore CsBr was mixed with EuOBr and placed in a container in a vacuum deposition chamber. The phosphor was deposited on an aluminum substrate having a thickness of 1.5 mm and a circular diameter of 40 mm.

The distance between the container and the substrate was 10 cm.  
25 During vapor deposition the substrate was rotated at a velocity of 12 rpm.

Before starting evaporation, the chamber was evacuated to a pressure of  $4.10^{-5}$  mbar. During the evaporation process Ar was introduced as an inert gas in the chamber.

30

Several screens were produced in order to provide a test material suitable for test with several differing protective coating application

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techniques.

Parylene C was applied on a phosphor screen by a low-temperature, low-pressure application technique. The dimer chloro-di-para-xylylene was evaporated at 150°C and broken down to the monomer at 690°C. The monomer vapor was guided to the vapor deposition chamber where polymerization took place on the phosphor screen surface.

Samples were covered with a coating of 10  $\mu\text{m}$  thickness.

A solution is made of 20 g of the polysilazane Kion VL20 of Kion Corporation, Columbus, Ohio USA, in a solvent mixture of 30 g of toluene and 30 g of methylethylketone. Hereto, 10 g of a 30 wt% solution of polymethymethacrylate-co-butylmethacrylate is added. As a thermal initiator, 5 g of tertiair-butylperoxy-2-ethylhexyl-carbonate was mixed into the solution, becoming a clear, colorless solution. The solution was applied by means of dipcoating onto the phosphor screen with a parylene-layer, and cured for 20 hours in a drying oven at 90°C. The cured polysilazane-acrylate coating with high abrasion resistivity, was a clear, transparent and colorless layer (coating A) having a thickness of about 10  $\mu\text{m}$ .

In a second application (coating B), 2 g of a polysilazane was dissolved in 10 g of toluene. Hereto, 2 g of a 20 wt% solution of dimethyl-2,2-azobis(2-methylpropionate) was added dropwise under strong homogenization. After 30 minutes of stirring, the solution was applied by means of bar-coating onto the phosphor screen with a parylene-layer, and cured for 1 hour at 120°C.

The cured coating combined high abrasion resistivity with elasticity and transparency.

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For coating C, a polysilazane solution was made by dissolving 20 g in 20 g of methylethylketone. Hereto, 20 g of Servocure RT184 of Servo, The Netherlands, was added, together with 20 g of Ebecryl 1290 by UCB Radcure, Belgium. The solution was homogenized by stirring  
5 during 2 hours. Then, 4 g of Darocur 1173 by Ciba, Germany, was added. The lacquer was applied by means of sieve printing and cured with strong UVA-light with an intensity of at least 200 mW/cm<sup>2</sup>.

In another application (coating D), a solution of polysiloxazane and urethane acrylates was sprayed onto the phosphor screen with a  
10 parylene-coat and cured under the influence of atmospheric moisture at 60°C during 20 hours, in order to become a 6 µm abrasion-resistant, clear, elastic, non-brittle layer.

The applied polymeric solution was a mixture of 7.5 g of  
15 poly(oxy-1,2-ethanediyl-hydro-(1-oxo-2-propenyloxy))-ether, 2.5 g of 2-ethyl-2(hydroxymethyl)-1,3-propanediol, 5 g of hexanediol-diacrylate, 15 g of a hexafunctional urethane-acrylate-oligomer and 60 g of Kion ML33/C33 by Kion Corporation, Columbus, USA, dissolved in 400 g of methylethylketone and 300 g of methoxypropanol.

20 In order to avoid cracks and irregularities due to shrinkage during curing when applying thick coatings, it is recommended to provide said thicker coatings by application of multilayers (double or even triple coatings of polysilazane precursor solutions).

25 The abrasion resistance of the applied coatings was evaluated with a Teledyne Taber 5130 Abraser with Calibrase CS10F elements, sandpaper P220 and a load of 250 g on each element, as described in ASTM D1044. Loss of layer mass was measured after 100 cycles.

30 For evaluating the resistance against atmospheric humidity, the samples were stored in a desiccator with a defined atmosphere of 87 % relative humidity at 25°C for one week. The gravimetric water



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absorption (expressed in mg) was observed with respect to the surface area (expressed in  $\text{cm}^2$ ). Results of both tests for screens having the compositions as indicated have been summarized in Table 1 hereinafter.

Table 1

Coating	ASTM D1044 test Mass loss	Water Absorption at 87% RH / 25 °C
No coating onto the phosphor needle layer	> 20 mg	total deterioration after less than 12 hrs
Parylene C layer 8 $\mu\text{m}$	10 mg	0.40 $\text{mg}/\text{cm}^2$
Parylene C + coating A	3.0 mg	0.20 $\text{mg}/\text{cm}^2$
Parylene C + coating B	1.5 mg	0.15 $\text{mg}/\text{cm}^2$
Parylene C + coating C	0.2 mg	0.10 $\text{mg}/\text{cm}^2$
Parylene C + coating D	0.5 mg	0.10 $\text{mg}/\text{cm}^2$

It has thus clearly been shown that, making use of a Teledyne Taber 5130 Abraser and with Calibrase CS10F elements, sandpaper P220 and a load of 250 g on each element as described in ASTM D1044, a mass loss of the surface layer of the screen of the present invention of not more than 3 mg is found, when measured after 100 cycles, and a water absorption of not more than 0.20  $\text{mg}/\text{cm}^2$ .

These results are clearly indicative for the effectiveness of wear (scratch) and moisture resistance of the protective layer combination applied to the binderless phosphor screen according to the present invention.

Manufacturing storage phosphor screens or panels and providing an excellent protection against moisture, both at the top side and at the

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edges of the phosphor screen or panel in a radiation detector has thus been shown to be attainable.

Having described in detail preferred embodiments of the current  
s invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the appending claims.